

Must-Knows: Unit 6 (Enzymes and Cell Respiration)

Ms. OK, AP Biology, 2014-2015

Test Format: 29 multiple choice questions, 1 short response question

Topic #1: Enzymes

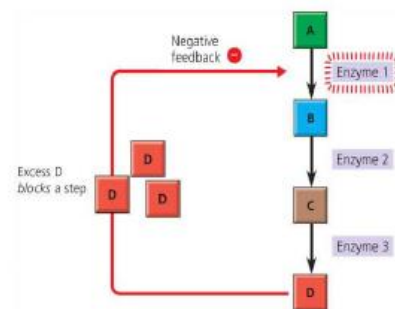
- How are competitive and noncompetitive inhibition of enzyme action different from one another? What are they both used to do?

In competitive inhibition, the inhibitor molecule is shaped like the substrate and binds to the active site to prevent the binding of the substrate. This lowers the rate of the enzyme-catalyzed reaction.

In noncompetitive inhibition, the inhibitor molecule is not shaped like the substrate and binds to a different region on the enzyme (not the active site). The binding of the inhibitor molecule to a different region, however, causes a shape change in the active site so that it is no longer able to bind to the substrate. This lowers the rate of the enzyme-catalyzed reaction.

- Compare / contrast negative and positive feedback.

In negative feedback, the end product of a multi-step reaction inhibits an enzyme used early in the reaction and causes a decrease in the amount of product formed. (In the image to the right, A is the reactant molecule at the beginning of the reaction. B and C are intermediate molecules, and D is the product molecule at the end of the reaction. Enzymes 1, 2, and 3 are used at various points during the multi-step reaction. With this example, negative feedback would involve product D inhibiting Enzyme 1.)



In positive feedback, the end product of a multi-step reaction activates any enzyme used in the reaction and causes an increase in the amount of product formed. (With the example image given above, positive feedback would involve product D activating Enzymes 1, 2, OR 3.)

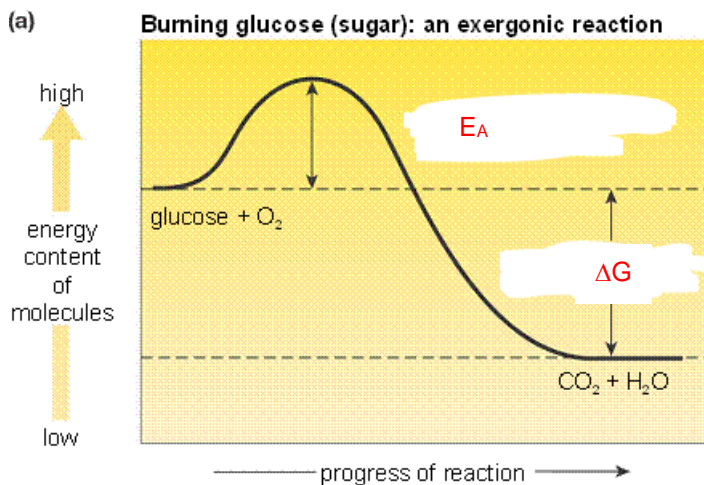
- In negative feedback, does the end product of a multi-step reaction typically inhibit an enzyme involved in an earlier or later step of the reaction? Why?

The end product inhibits an enzyme involved in an earlier step of the reaction so that the process is stopped before energy is wasted making intermediate molecules (ex: B and C in the image above).

- How does an enzyme affect the activation energy of a reaction? How does an enzyme affect the ΔG (change in free energy) of a reaction (i.e. the change in energy from the reactants to the products)? Label the activation energy (E_A) and change in free energy (ΔG) of the reaction shown in the graph to the right.

An enzyme lowers the activation energy of a reaction. (Remember, the activation energy is the energy required to start a reaction.)

An enzyme does not change the ΔG of a reaction.



5. How does boiling an enzyme (i.e. subjecting it to extreme temperature changes) affect its ability to catalyze (speed up) a reaction?

Boiling an enzyme causes the enzyme to denature (lose its shape). If the enzyme loses its shape, the substrate will no longer be able to fit into the enzyme's active site. Therefore, the rate of reaction will decrease significantly because the enzyme will not be able to catalyze the reaction.

6. How does decreasing the temperature affect an enzyme's ability to catalyze a reaction?

Decreasing the temperature lowers the rate of reaction because molecules move more slowly at lower temperatures. Therefore, it will take longer for a substrate to "bump into" an enzyme's active site due to random molecular movement at lower temperatures.

7. Why does denaturation of an enzyme affect its ability to bind to the substrate(s)?

See #5 above.

8. Which of the following could you use to measure the rate of an enzyme-catalyzed reaction (circle all that apply)?

- A. The amount of enzyme
- B. The rate of substrate destruction
- C. The rate of product formation

(The amount of enzyme cannot be used to measure the rate of reaction because the enzyme remains unchanged during the reaction and can be reused to assist with the same reaction. Therefore, the amount of enzyme should stay constant unless more enzyme is directly added by the researcher.

9. Why does the rate of an enzyme-catalyzed reaction stop increasing at very high substrate concentrations?

Once all the enzyme molecules are "saturated" with substrate (i.e. their active sites are all filled with substrate molecules), adding more substrate will not increase the rate of reaction because the substrate molecules have no enzymes to bind to.

Topics #2 and #3: Aerobic and Anaerobic Cell Respiration

10. What evidence do scientists have to indicate that glycolysis is an ancient process?

Glycolysis is found in all living organisms (regardless of whether they use aerobic respiration, anaerobic respiration, or both). It does not require oxygen, so it is a process that probably evolved when there was no oxygen in the atmosphere of early Earth. Also, it occurs in the cytoplasm of the cell (not in a membrane-bound organelle), indicating it evolved when only prokaryotic cells were present on Earth.

11. What are the reactants (starting molecules) and products (ending molecules) of glycolysis?

Reactants = glucose, 2 ADP and 2 Pi, and 2 NAD⁺
Products = 2 pyruvates, 2 ATP, and 2 NADH

12. Describe the amount and type of ATP production during glycolysis. (Note: The type of ATP production refers to substrate-level phosphorylation vs. oxidative phosphorylation.)

Glycolysis produces 2 ATP molecules through substrate-level phosphorylation.

13. What are the reactants (starting molecules) and products (ending molecules) of the intermediate step between glycolysis and the Krebs / citric acid cycle in which pyruvate is converted to Acetyl CoA?

Reactants = 2 pyruvate, 2 NAD⁺
Products = 2 Acetyl CoA, 2 NADH, 2 CO

14. What are the reactants (starting molecules) and products (ending molecules) of the Krebs / citric acid cycle?

Reactants = 2 Acetyl CoA, 2 ADP and 2 Pi, 6 NAD⁺ and 2 FAD
Products = 2 CO₂, 2 ATP, 6 NADH and 2FADH₂

15. After the Krebs cycle, how is most of the energy from the original glucose molecule stored?

As high-energy electrons captured from glucose and carried by NADH and FADH₂ to the electron transport chain.

16. How are high-energy electrons from NADH and FADH₂ used during the electron transport chain?

NADH and FADH₂ “drop” their high energy electrons off at the electron transport chain. In the electron transport chain, membrane electron carriers / protein pumps in the inner mitochondrial membrane use the energy from the electrons to pump H⁺ ions across the inner membrane from the matrix to the intermembrane space. This creates an electrochemical / concentration gradient of H⁺ ions (aka proton motive force), which can be “used” for ATP synthesis (see #19).

17. How is oxygen gas (O₂) used during the electron transport chain?

Oxygen gas is the final electron acceptor in the electron transport chain. Oxygen gas combines with electrons and free-floating H⁺ ions to form H₂O (water!).

18. Why are their folds (aka cristae) in the inner mitochondrial membrane?

The folds increase the surface area of the inner mitochondrial membrane. If there is more membrane, there is more space for the protein complexes of the electron transport chain. If there are more electron transport chains, more ATP can be synthesized.

19. Define “proton motive force.” How is this used during the electron transport chain?

The proton motive force is the electrochemical / concentration gradient created by pumping H⁺ ions from the matrix to the intermembrane space. As a result of this force, H⁺ “wants” to flow back down its gradient from a high concentration in the intermembrane space to a low concentration in the matrix. The only way that it can flow through the inner membrane is by passing through the ATP synthase protein. As H⁺ ions flow through ATP synthase, the protein turns and causes ADP and Pi (which are just hanging out in the matrix) to “squish” together and form ATP.

20. How is oxidative phosphorylation / chemiosmosis (the type of ATP production that occurs in the electron transport chain) different from substrate-level phosphorylation? Is there more or less ATP made during oxidative phosphorylation than substrate-level phosphorylation?

Substrate-level phosphorylation (occurs during glycolysis and the Krebs cycle) = A type of ATP synthesis where we take a phosphate group from glucose, pyruvate, etc. and stick it to ADP

Oxidative phosphorylation (occurs during the electron transport chain) = A type of ATP synthesis that uses ATP synthase and an H⁺ gradient to make ATP

Oxidative phosphorylation makes A LOT more ATP than substrate-level phosphorylation. For every glucose molecule, 4 ATP are made during glycolysis and the Krebs cycle by substrate-level phosphorylation, whereas 32-34 ATP are made during the electron transport chain by oxidative phosphorylation.

21. How is aerobic respiration different from anaerobic respiration (aka fermentation)? Which steps of aerobic respiration (i.e. glycolysis, the conversion of pyruvate to acetyl CoA, the Krebs cycle, or the electron transport chain) occur during anaerobic respiration?

Aerobic respiration requires oxygen, whereas anaerobic respiration does not. Glycolysis is the only step of aerobic respiration that occurs during anaerobic respiration.

22. Why does NAD⁺ need to be regenerated from NADH for glycolysis to continue? How is this accomplished in lactic acid fermentation vs. alcoholic fermentation?

NAD⁺ accepts electrons from glucose during the breakdown of glucose to pyruvate. If NAD⁺ is not available to accept electrons, glucose cannot be broken down and glycolysis cannot continue.

During lactic acid fermentation, pyruvate accepts electrons from NADH during its conversion to lactic acid. Once NADH has lost these electrons, it becomes NAD⁺ again.

During alcoholic fermentation, pyruvate accepts electrons from NADH during its conversion to ethyl alcohol and CO₂. Once NADH has lost these electrons, it becomes NAD⁺ again.

23. In what types of organisms / cells does each type of fermentation occur?

Lactic acid fermentation occurs in the muscle cells of humans and other animals during periods of strenuous exercise where there is not enough oxygen for aerobic respiration to continue. Certain types of bacteria also use lactic acid fermentation.

Alcoholic fermentation occurs in yeast cells. (We use the products of yeast cell alcoholic fermentation in the process of making bread, beer, and wine.) Certain types of bacteria also use alcoholic fermentation.

Science Skills

An experiment to measure the rate of respiration in crickets and mice at 10°C and 25°C was performed using a respirometer, an apparatus that measures changes in gas volume. Respiration was measured in mL of O₂ consumed per gram of organism over several five-minute trials and the following data were obtained.

24. How will carbon dioxide produced by the crickets and mice affect the measurements of average respiration (mL O₂ / g / min)?

The production of carbon dioxide gas may cause the respirometer to appear to contain more oxygen than it truly does. Therefore, the amount of oxygen gas consumed (lost from the respirometer) will appear smaller than it actually is. The measurements of average respiration will be inaccurately small.

In a respirometer lab, KOH is present in the respirometer. KOH can combine with CO₂ to form K₂CO₃, a solid precipitate (powder). This solid precipitate does not affect the gas volume in the respirometer.

25. Why do you think the rate of respiration is higher at lower temperatures for mice?

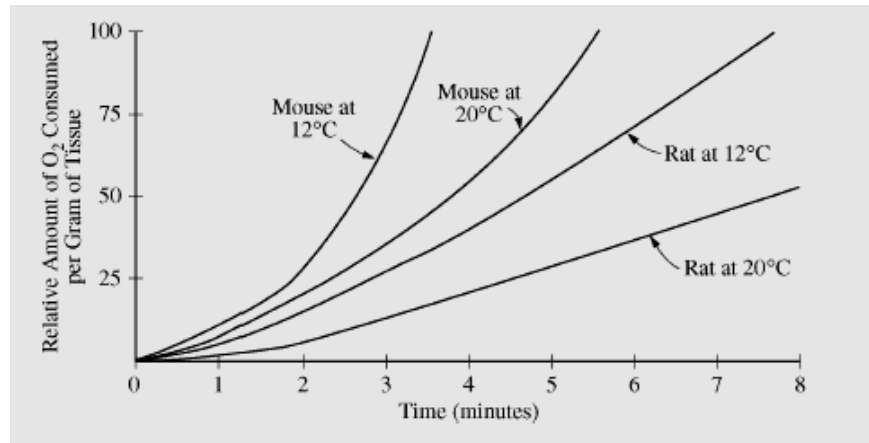
To maintain a stable body temperature at low outside temperatures, mice must use more energy from ATP. If more ATP is required, there will be a higher rate of cellular respiration (since cellular respiration makes ATP!).

Organism	Temperature (°C)	Average respiration (mL O ₂ /g/min)
Mouse	10	0.0518
Mouse	25	0.0321
Cricket	10	0.0013
Cricket	25	0.0038

26. If mice are endotherms (regulate their temperature by using the energy from ATP to generate body heat) and crickets are ectotherms (regulate their temperature using behaviors like basking in the sun), how do you explain the difference in rate of respiration for mice vs. crickets at both 10 degrees Celsius and 25 degrees Celsius?

The rate of respiration is higher for mice at both temperatures because mice use more ATP to maintain their body temperature.

A respirometer is a container used to measure the amount of oxygen consumed by an organism. A respirometer was used to determine how environmental temperature affects the uptake of oxygen in one 300-gram rat and one 50-gram mouse. The results of this experiment are shown on the graph below.



27. From the data given above, what can you conclude about the effect of temperature and body mass on the rate of cellular respiration?

The rate of respiration increases as temperature decreases.

The rate of respiration increases as body mass decreases.